DEPARTMENT OF EARTH AND PLANETARY SCIENCES

University of Pittsburgh

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Semi-Annual Report

to the

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for

STUDIES RELATED TO THE SURFACES OF THE MOON AND PLANETS

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covering the period

October 1, 1972 - March 31, 1973

and

April 1, 1973 - September 30, 1973

Principal Investigator

Bruce Hapke

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I. INTRODUCTION

This report is a summary of the research performed under NASA Grant NGL 39-011-085 for studies related to the surfaces of the moon and planets during the period April 1, 1973 - September 30, 1973. During the preparation of this report it was realized that a semi-annual report covering the period October 1, 1972 - March 31, 1973 had inadvertantly not been submitted; therefore the present report describes studies carried on during the latter period also.

The research projects continued during this time include studies of the transmission and reflection spectra of silicate minerals and glasses, and particularly the changes which might be induced by solar wind irradiation and meteorite impacts. The main achievements of this period include the following: the synthesis of glasses and thin films of lunar composition prepared under a variety of conditions, the preliminary analysis of various properties of these materials using optical, electron microprobe, Mossbauer, and magnetic methods, the development of a new method for rapid measurement of the transmission spectrum of highly absorbing materials, and the development of a theoretical model which accounts for the reflection spectrum of the moon over the wavelength range from 0.1μ to 3.0μ.

II. DESCRIPTION OF RESEARCH

A. GLASSES AND FILMS

A number of silicate glasses and films of composition similar to lunar materials, but with varying amounts of Fe and Ti, have been synthesized. Their optical, chemical and magnetic properties have been measured in order to elucidate the nature of the absorption bands which are present in the reflection spectra of lunar regolith.

The following strong absorption bands have been observed in the glasses:

Below 0.2μ, with tail extending above 0.2μ; all glasses; probably charge-transfer involving cations.

0.25μ; all glasses; probably charge-transfer involving Fe^{+3} impurities.

0.38μ; only in glasses containing TiO_2; probably charge-transfer band.

0.50μ; only in glasses containing TiO_2; probably d-d transition of Ti^{+3} ion, but may also be charge-transfer band involving Ti^{+3} ion.

0.60μ; only in glasses containing large amount of Fe^{+3}; probably Fe^{+3} - Fe^{+2} charge-transfer band.

1.0μ; only in glasses containing FeO; due to d-d transition in Fe^{+2} ion.

The addition of 2% metallic Fe lowers the spectrum slightly at all wavelengths, but does not cause any discrete bands.

In previous studies of glasses of lunar composition synthesized under reducing conditions, we had been unable to make a glass which was as absorbing in the 0.6-0.7μ region as lunar regolith. We suggested that the reason other workers had been successful in duplicating the lunar spectrum using vitrified basalt was because their synthesizing conditions were inadvertently oxidizing. The present studies further confirm this suggestion, since the 0.6μ absorption band occurs only in glasses with a large Fe^{+3}/Fe^{+2} ratio. The relative abundance of Fe^{+3}, Fe^{+2} and Fe^{0} were measured using Mossbauer techniques.

Films formed by sputtering and thermal evaporation remain the only materials we have been able to synthesize under chemically neutral or reducing conditions which approximate the lunar spectrum. Even with these films some problems remain: the films appear to be too dark in the UV to match the moon, in view of the results of Fastie, et al. with the Apollo 17 UV spectrometer. Also, the cause of the high absorption in the films remains abscure.

In order to further understand the light-absorbing mechanisms in the films, preliminary analyses of the films and their parent glasses were carried out using the electron microprobe at Penn State. Relative to the parent glasses, the evaporated films were found to be enriched in the alkali elements, and Fe and Si, and depleted in Ti, Al, Mg and Ca. Apparently during evaporation the components of the glass are transferred roughly in proportion to the vapor pressure of the individual oxides. Thus in the evaporated films we appear to be dealing primarily with a Fe-Si-O system. By contrast, in the sputtered film, all cations were transferred, but the film was quite deficient in O, and we appear to be dealing with a strongly non-stoichiometric system. Because of the highly unusual (to geochemists) nature of these films we have also requested Dr. T. Bunch of NASA/Ames to analyze them for us. This study is currently being carried out, but preliminary data tend to confirm the earlier results.

In the lunar fines the optical and magnetic properties are observed to be correlated, the most magnetic fraction having the lowest albedo. Thus the saturation remanences of several of the glasses were measured, using the facilities of Dr. M. Fuller at Pitt. The remanences of the films were found to be one to two orders of magnitude greater than the parent glasses, indicating the presence in abundance of discrete, submicroscopic, ferromagnetic phases, even though the films appear homogeneous under the petrographic microscope.

B. EXPERIMENTAL TECHNIQUES

As part of the present study it was desired to measure the transmission spectra of highly absorbing materials. Using conventional techniques this would have required the grinding and polishing of a large number of thin sections of thickness less than 50μ. Instead a new method was developed by which the spectrum of a few micrograms of material in powder form can be rapidly measured.

If one attempts to measure the transmission spectrum of a layer of powder on a glass plate, one finds that the light transmitted by the holes between grains completely swamps any light transmitted through the grains themselves. Consequently, a modified transmission method was developed whereby the light in the spectrophotometer beam is first deflected using a fused silica prism before falling on a thin layer of grains. Only light scattered by the grains (which is mainly transmitted light plus a small amount of surface reflection) enters the detector. This method has greatly facilitated our measurements.

C. THEORETICAL LUNAR SPECTRUM

A theoretical model which accounts for the lunar reflection spectrum over the range 0.1 - 3.0μ in a very simple manner has been developed.

The model rests on the following observations. The lunar reflection spectrum R can be converted into the spectrum of the averaged, effective, single-scattering albedo w of a grain of lunar soil using the Kubelka-Munk equation. It is found that w is constant from 0.1 to 0.2μ and $w = (a + b/\lambda)^{-1}$ from 0.2 - 3.0μ. The conventional explanation is that the spectrum is due to a large number of overlapping absorption bands. A simple, alternative explanation is that the soil consists of two components: a weakly-absorbing material with average particle size large compared with λ (i.e., pulverized crystalline rock and glass), plus about 1% of a highly absorbing material of average particle size of the order of 0.07μ. At present there appears to be no strong evidence against the model. We are currently seeking evidence for such a component in the literature.

III. MEETINGS ATTENDED AND PAPERS GIVEN

A. MEETINGS

B. Hapke attended the IAU Colloquium 23 on Polarimetry in Optical Astronomy, Tucson, November, 1972.

W. Cassidy attended the 4th Lunar Science Conference, Houston, March, 1973.

B. Hapke attended the annual AGU meeting, Washington, April, 1973, and delivered a paper entitled, "Chemical, Magnetic and Optical Characterizations of Glasses Produced by Simulated Lunar Surface Processes".

E. Wells attended the Charge-Transfer Conference, Boston, April, 1973.

B. Hapke attended the Symposium on the Moon in honor of Harold Urey's 80th birthday, Houston, April, 1973, and delivered an invited paper entitled, "Darkening of Silicate Rocks by Solar Wind Sputtering".

In addition, W. Cassidy traveled to State College, Pa. twice to use the electron microprobe facilities at Penn State.

B. PAPERS PUBLISHED

B. Hapke (1973) Darkening of Silicate Rock Powders by Solar Wind Sputtering, The Moon, 7, 342-355.

IV. PERSONNEL

The following persons have contributed to the work reported here:

B. Hapke, Principal Investigator	20%
W. Cassidy, Co-Investigator	10%
E. Wells, Graduate Student Research Assistant	25%
R. Nelson, Graduate Student Research Assistant	25%
E. Baier, Graduate Student Research Assistant	25%
L. Trucano, Secretary	25%